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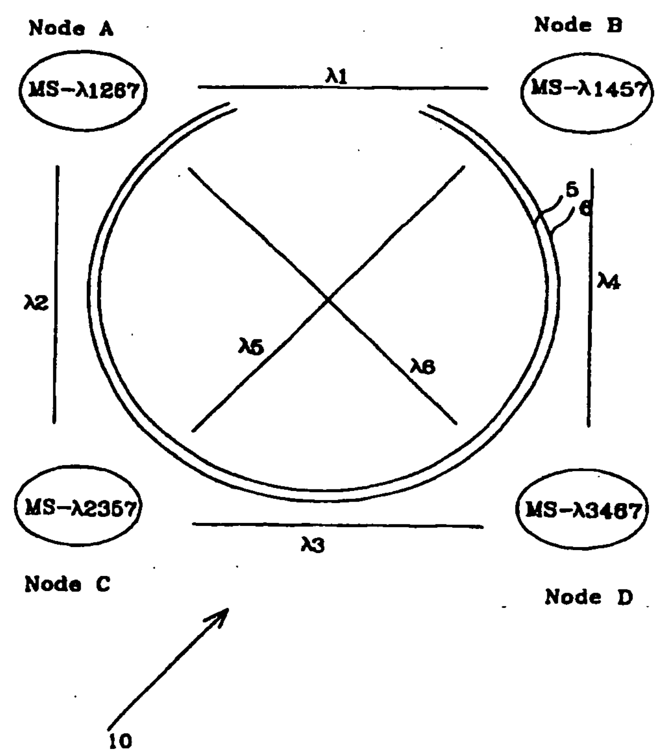
(54) Title: CHANNEL PROTECTION IN DATA-COMMUNICATION AND DATA TELECOMMUNICATION SYSTEM

(57) Abstract

The present invention relates to an optical fibre network that includes a cable having at least two optical fibres and at least two nodes interconnected with the cable, so that the nodes will be disposed in a ring. The nodes and the cable together form a bidirectional bus for transmitting and receiving on wavelength channels. Each node includes at least one spare transmitter and at least one spare receiver having a particular wavelength, and the network includes means for detecting faults on a transmitter/receiver in a node. The invention also relates to a method of detecting faults in the nodes and of switching from a degraded transmitter/receiver to the spare transmitter/spare receiver in the abovementioned optical fibre network.



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CHANNEL PROTECTION IN DATA-COMMUNICATION AND DATA TELE-COMMUNICATION SYSTEM

FIELD OF INVENTION

The present invention relates to an arrangement and a method for channel protection in optical multi-channel systems.

DESCRIPTION OF THE BACKGROUND ART

Optical fibres are being used to an ever increasing extent as transmission media in the field of telecommunications and data communications. The use of light signals for communication enables very fast data transmissions to be achieved.

One method of communicating over a common optical medium is to transmit a plurality of light signals via independent wavelength channels. This technique is called wavelength multiplexing (WDM).

Several solutions for interconnecting network nodes with the aid of rings or buses for instance, are known to the art.

In an optical network that includes N number of nodes connected in accordance with a ring concept, communication between the nodes can be effected unidirectionally through one fibre in one direction, or bidirectionally through two fibres, where communication between the nodes in said one fibre is in an opposite direction to the direction of communication through the other fibre. When each node communicates with each other node via a unique wavelength channel, then $\frac{N(N-1)}{2}$ wavelength channels will occur on each optical fibre.

4-fibre ring solutions are also possible, these solutions having higher capacities.

In an optical network in which nodes are interconnected in accordance with the bus concept, communication is always bidirectional. Also known are buses and rings in which wavelengths are re-used. The used wavelength is filtered out from the fibre and a new channel having the same wavelength is used instead.

A flexible bidirectional bus having fixed nodes in a WDM-system is created by intentionally deactivating the optical fibres at an ON/OFF switch or at a component that has the same function, for instance an optical amplifier. The transmitters S in each node transmit in both bus directions, and the receiver M in each node is connected to receive from both bus directions, said receivers being preceded by a wavelength selective filter. The transmitters S are interconnected with the aid of multiplexors, which may be typical fibre couplers in their simplest form. The channels are decoupled with the aid of the multiplexors, which may comprise fibre couplers combined with optical filters or more advanced WDM-components. The filtered-out channels are received by the receivers M in the node. The nodes will preferably communicate in pairs on the same wavelength channel "λn" . Because the concept is a bus concept, each receiver will receive only one given signal from one fibre, since the other fibre is broken by the ON/OFF switch. In the event of a cable breakage, the ON/OFF switch is closed and all connections restored.

The number of transmitted channels in the fibre can be reduced by placing wavelength filters in the nodes, these filters removing unnecessary channels downstream. The number of wavelengths required in the aforedescribed concept, which can be

referred to as a flexible bus having fixed nodes, is $\frac{N(N-1)}{2}$, where N is the number of nodes in the bus.

A variant of the fixed node bus concept is a flexible bus whose nodes can be rearranged. The transmitters and receivers transmit and receive only in one direction, depending on where the communicating nodes are located. As in the above case, the ring is broken and thus forms a bus. A channel is demultiplexed from the fibre and received in a receiver. Another channel can then be multiplexed in on the same wavelength again. This technique thus enables wavelengths to be re-used. The number of channels required in this concept is $\frac{N^2}{4}$ or $\frac{N^2-1}{4}$, depending on whether the node number N is even or odd.

Prior patent publications US,A,5 365 510, 5 179 548 and EP,A1,677 936 describe various ways of dealing with cable breakages in optical bus networks. In brief, the protective systems involve connecting to the various system nodes one spare fibre in the case of unidirectional communication and two spare fibres in the case of bidirectional communication, in a manner similar to standard connections but separated physically therefrom. Communication on the spare fibres is commenced when a standard fibre has broken at some point or other. In the event of a node fault, a head is formed on one side of the node and a tail on the other side thereof, causing the node to be disconnected from the network and communication to continue between the remaining network nodes.

SUMMARY OF THE INVENTION

A break in communication in an optical bus network may have several causes. A number of solutions are known for restoring

communication in the event of a cable breakage. However, when using WDM, no technique is known which solves the problem in a cost effective manner, since either a transmitter or a receiver in a node degrades or breaks down.

One object of the present invention is to provide channel protection in WDM-systems in a cost effective manner.

When a receiver in a node degrades or breaks down, the receiver switches off associated transmitters in the same node and switches to a reserve transmitter and to a reserve receiver. The same thing happens when the transmitter degrades or breaks down in a node, i.e. the transmitter will switch off associated receivers and switch to a reserve transmitter and to a reserve receiver. Receiving nodes sense that standard wavelength channels have disappeared and therefore switch to their reserve transmitters and reserve receivers, therewith restoring communication.

The following applies to both a flexible bidirectional bus having fixed nodes and a flexible bidirectional bus whose nodes can be rearranged.

Each node is equipped with at least one extra transmitter and at least one extra receiver for one and the same reserve or spare channel (wavelength). The spare channel is implemented in the same way as the remaining channels in the case of a flexible bus. In the case of a flexible bus whose nodes can be rearranged, the spare channel is implemented in the same way as with the flexible bus whose nodes are fixed. Switching from the degraded channel to the spare channel can either be effected via a crossmux switch or via a simple mechanical switch. For instance, if node A and node B communicate with each other on a

wavelength λ1 and the receiver or transmitter in node A breaks down, both transmission and reception are switched to the spare channel. Node B will lose the channel on λ1 and therewith switches its transmission and reception to the spare channel. The nodes will thereby re-establish connection with one another, irrespective of whether it is a transmitter or a receiver that has broken down.

A flexible bus that includes channel protection is characterized, among other things, in that a transmitted channel is unable to return to the transmitting node. Another characteristic feature is that all nodes have access to at least one common spare wavelength.

One advantage afforded by the present invention is that the same transmitters and receivers can be used to protect all connections. In other words, we have 1:N protections both with respect to wavelength channels and transmitter/receiver pairs.

Another advantage is that one single common wavelength can be used to protect all channels, therewith preventing wastage of optical wavelength space.

Another advantage is that the logic required to rectify channel faults is very simple.

Another advantage is that because the wavelength channel is distributed over the entire network it can also be used for broadcasting or for flexibly increasing capacity between two nodes.

The invention will now be described in more detail with reference to preferred embodiments thereof and also with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates communication between nodes in an optical network, in accordance with the invention.

Figure 2 illustrates a flexible bus having fixed nodes in a network, in accordance with the invention.

Figure 3 illustrates a re-arrangeable node in a network according to the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 illustrates communication between four nodes A, B, C and D in a network 10 constructed in accordance with the fixed node concept and having two optical fibres 5, 6. Although the network illustrated in Figure 1 is shown to include four nodes, it will be understood that the number of nodes in the network may be fewer or greater than four. The number of wavelengths required in the illustrated case is 6 ($\frac{N(N-1)}{2}$, where N is the number of nodes in the network), λ1 - λ6. The letters MS in Figure 1 stand for receiver and transmitter. The following letter and digit combinations designate the wavelengths used in the node. λ 1267 in node A signifies that node A and node B communicate with one another on the wavelength channel λ1, node A and node C communicate with one another on the wavelength channel λ2 and node A and node D communicate with one another on the wavelength channel λ 6. Each node has been provided with a spare transmitter, Sreserv, and a spare receiver, Mreserv, having the wavelength λ7. The digit-letter combination of each node will therefore include the digit 7.

In the case of the Figure 1 illustration, each node communicates with each other node on a specific wavelength channel. For instance node A communicates with node B on the wavelength channel λ1. The transmitting node is called the source node and the receiving node is called the destination node. Assume that node A and node B communicate with one another on the wavelength channel λ1 and that the receiver M1 or the transmitter S1 breaks down in node A. Both transmission and reception will then be switched to the spare channel λ7. Node B will lose the channel on λ1 and consequently switch its transmission and reception to the spare channel λ7. The nodes have therewith re-established connection with one another, irrespective of whether it was a transmitter or a receiver that broke down. The decision made by the protection switch can be taken locally with the aid of very simple logic.

An alternative method to that described above is one in which only the transmitter and the receiver communicate with one another and which switch to the spare channel when either the transmitter or the receive degrades. The bidirectional connection would then utilize two wavelengths, the original wavelength and the spare wavelength. This method necessitates the nodes communicating with one another via a monitoring system.

In order to avoid confusing a channel fault with cable breakage logic, the channel protection is preferably coordinated with cable protection logic.

Figure 2 illustrates a flexible bus having fixed nodes. One of the four nodes in the bus is enlarged in the figure. The node includes four transmitters and four receivers, of which receiver Mr and transmitter Sr are spares. A fixed-node flexible bus in a

WDM-system is created by breaking two adjacent ON/OFF-switches between two nodes. The transmitters S of each node transmit in both directions of the bus, and the receivers M in each node are coupled to receive from both bus directions, said receivers being preceded by a wavelength selective filter.

Each node includes means for applying and selecting particular wavelength channels, i.e. multiplex channels, referenced MULT in Figure 2, and demultiplex channels, refereced DEMULT in Figure 2. In their simplest form, the multiplexors on which the transmitters S and Sr transmit light on the fibres may be fibre couplers. Demultiplexing from the fibres may, in turn, also be effected by typical fibre couplers, in its simplest form. The decoupled light then passes through a wavelength demultiplexor, which filters out the channel or channels that are to be received. A receiver M and Mr is then coupled to this multiplexor. The wavelength-demultiplexor may be a combination of standard optical couplers and optical filters, or integrated as a unit. As beforementioned, the number of wavelength channels required in this concept is , where N is the number of nodes in the bus.

Figure 3 illustrates a node in a bidirectional bus according to the concept with nodes that can be arranged. Rearrangeable nodes implies that the transmitters S and the receivers M transmit and receive only in one direction, depending on where the communicating nodes are located. This concept enables wavelength channels to be re-used.

Each node includes means for selecting particular wavelength channels. The wavelength demultiplexor (elector), DMu, may be a combination of conventional optical couplers and optical filters, or integrated as a unit.

Receiver M is coupled to each selected wavelength.

As shown in Figure 3, the flexible bus having re-arrangeable nodes includes four receivers M and four transmitters S, of which one receiver Mr and one transmitter Sr are spares.

The node includes three demultiplexors, DMu, for branching-off the wavelength channels to respective receivers M, and three multiplexors Mu for applying to said two optical fibres 5 and 6 wavelength channels from corresponding transmitters S.

Since the protective channel shall be able to pass from and to all nodes, it may not be filtered out from the fibre in the nodes. With respect to the protective channel, activation and deactivation must be effected with a wavelength-independent coupler, for instance with a conventional coupler with which only a part of the power is lost or applied.

The node also includes five 2x2-protection couplers V1-V5 so as to enable requisite switching to be effected in the node in response to changes in the bus network. Each protection coupler includes two inputs and two outputs, of which a first input is connected to a first optical fibre 5 and a second input is connected to a second optical fibre 6. Correspondingly, a first output is connected to the first optical fibre 5 and a second output is connected to the second optical fibre 6. In a first state of the coupler, or switch, signals from the input connected to the first optical fibre 5 are coupled to the output connected to this fibre, whereas signals from the second input connected to the second optical fibre 6 are coupled to the output connected to the same fibre. In a second state of the switch, a signal from the first input connected to the first optical fibre 5 is forwarded to the output connected to the

second optical fibre 6. Correspondingly, the signal on the second input connected to the second optical fibre 6 is switched to the first output connected to the first optical fibre 5.

The number of wavelength channels required is $\frac{N^2}{4}$ or $\frac{N^2-1}{4}$, depending on whether the nodes N are an even or odd number.

Each node includes means for detecting channel faults. A channel fault can be detected as a loss of power incoming from the fibre, as a loss of the incoming channel, or because the own transmitter of the node has been degraded. This enables each node to make a local protection-switching decision.

Each node includes at least one spare transmitter and at least one spare receiver.

It will be understood that the invention is not restricted to the aforedescribed and illustrated exemplifying embodiments thereof and that modifications can be made within the scope of the following claims.

CLAIMS

1. An optical fibre network comprising a cable having at least two optical fibres and at least two nodes interconnected by said cable, such that the nodes are disposed in a ring where the nodes and cable together form a bidirectional bus for transmitting and receiving on wavelength channels, **characterized** in that each node includes at least one spare transmitter and at least one spare receiver having a particular spare wavelength; and in that the network includes means for detecting faults on a transmitter/receiver in a node.

2. An optical fibre network according to Claim 1, **characterized** in that the spare transmitter/spare transmitters functions/function to transmit the spare wavelength in both directions of the bus; and in that the receivers function to receive the spare wavelength in both directions of said bus.

3. An optical fibre network according to Claim 1, **characterized** in that the network includes means for switching from a damaged transmitter to both a spare transmitter and a spare receiver in one and the same node; and in that the network includes means for switching to the spare transmitter and the spare receiver in a destination node.

4. An optical fibre network according to Claim 1, **characterized** in that the network includes means for switching from a damaged receiver to both the spare transmitter and spare receiver in one and the same node; and in that the network includes means for switching to the spare transmitter and to the spare receiver in a source node.

5. An optical fibre network according to Claim 1, **characterized** in that the nodes include means for switching from a damaged

transmitter in one node to a spare transmitter in the same node; and in that the network and the nodes include means for switching to a spare receiver in a destination node.

6. An optical fibre network according to Claim 1, **characterized** in that the nodes include means for switching from a damaged receiver in one node to the spare receiver in the same node; and in that the network and the nodes include means for switching to the spare transmitter in a source node.

7. A method for maintaining communication in an optical fibre network comprising a cable having at least two optical fibres, and at least two nodes interconnected by said cable so that the nodes are disposed in a ring, wherein the nodes and the cable together form a bidirectional bus for transmitting and receiving on wavelength channels when one node degrades or breaks down, **characterized** in that a node detects that communication on a certain wavelength channel with a certain node has broken down or has degraded; in that the communicating nodes switch from the lost channel to a spare channel of particular wavelength.

8. A method according to Claim 7, **characterized** in that switching is effected so that transmission and reception will take place on said new spare channel in only one direction; and in that the original channel is still used for communication in the other direction.

9. A method according to Claim 7, **characterized** in that switching is effected so that transmission and reception take place on the new spare channel in both directions, so that communication between the nodes is switched entirely from the standard channel to the spare channel.

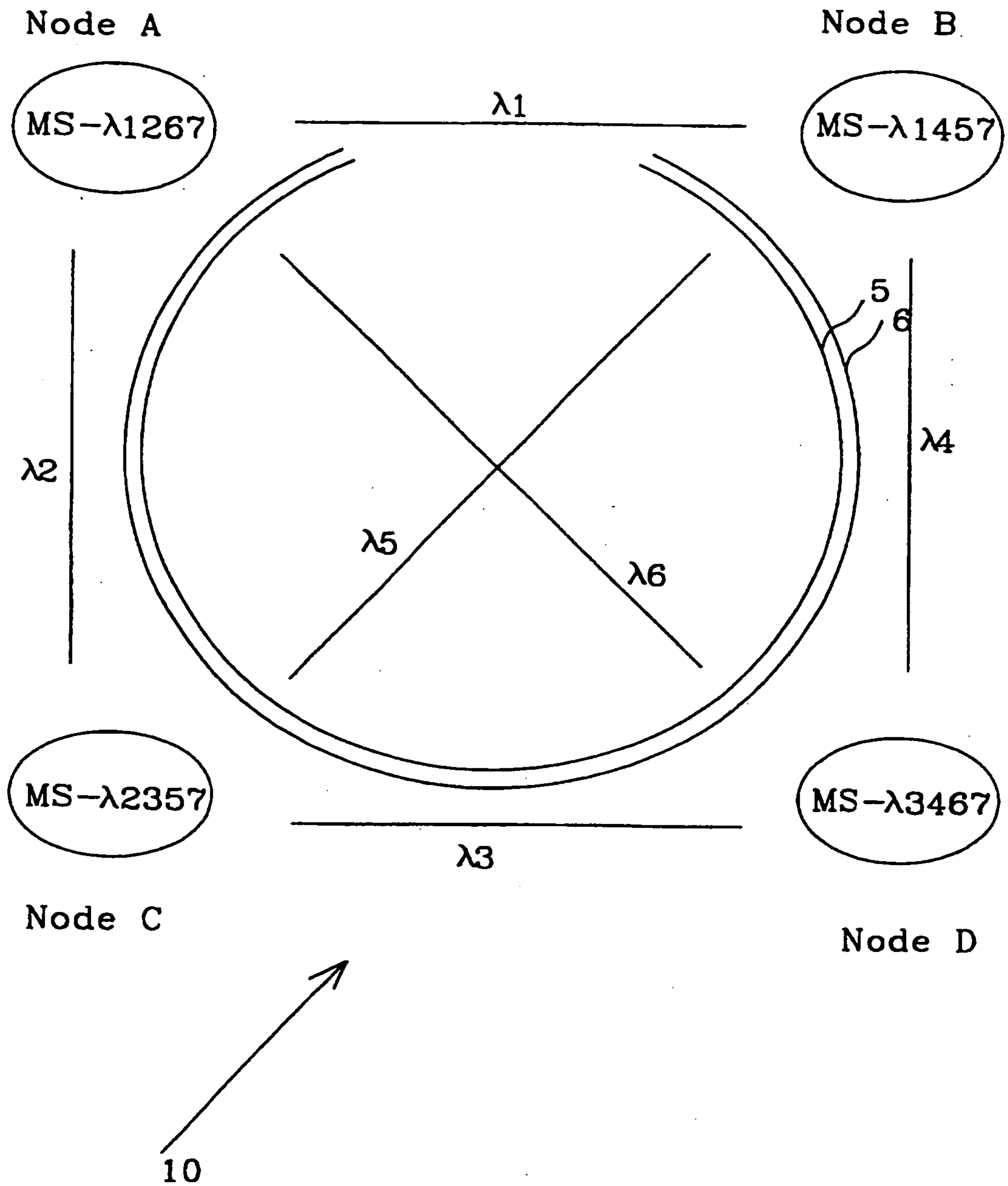
Node A
Node B
MS-λ1267
MS-λ1457
λ1
λ2
λ4
5
6
λ5
λ6
MS-λ2357
MS-λ3467
λ3
Node C
Node D
10

Fig.1

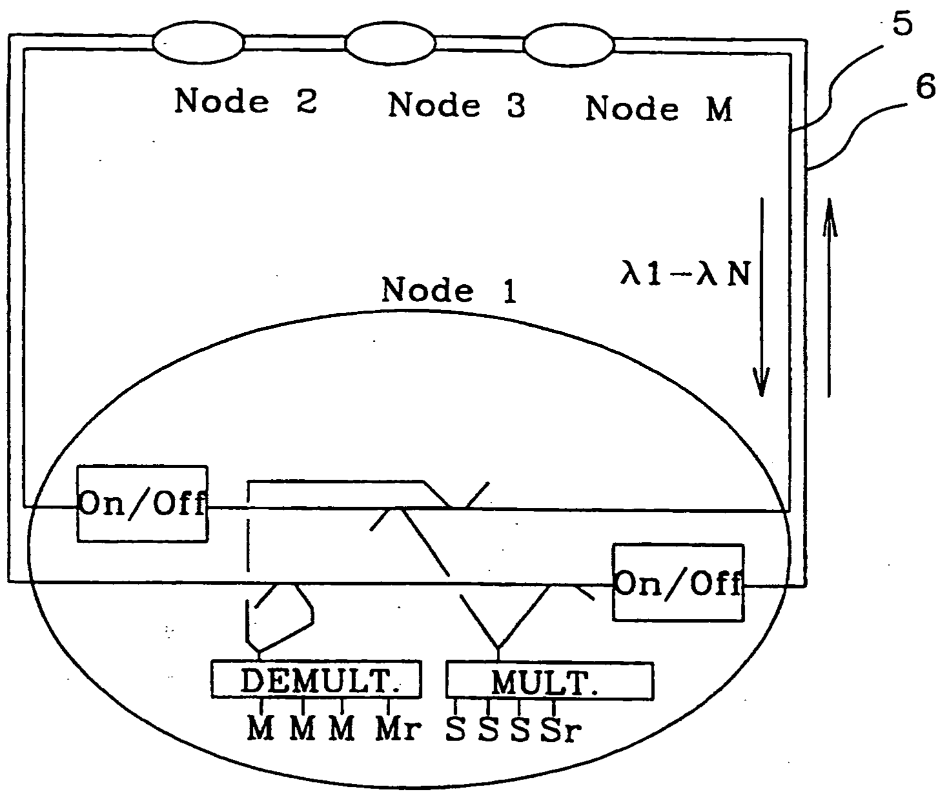
5
6
Node 2
Node 3
Node M
λ1–λN
Node 1
On/Off
On/Off
DEMULT.
MULT.
M M M Mr
S S S Sr

Fig.2

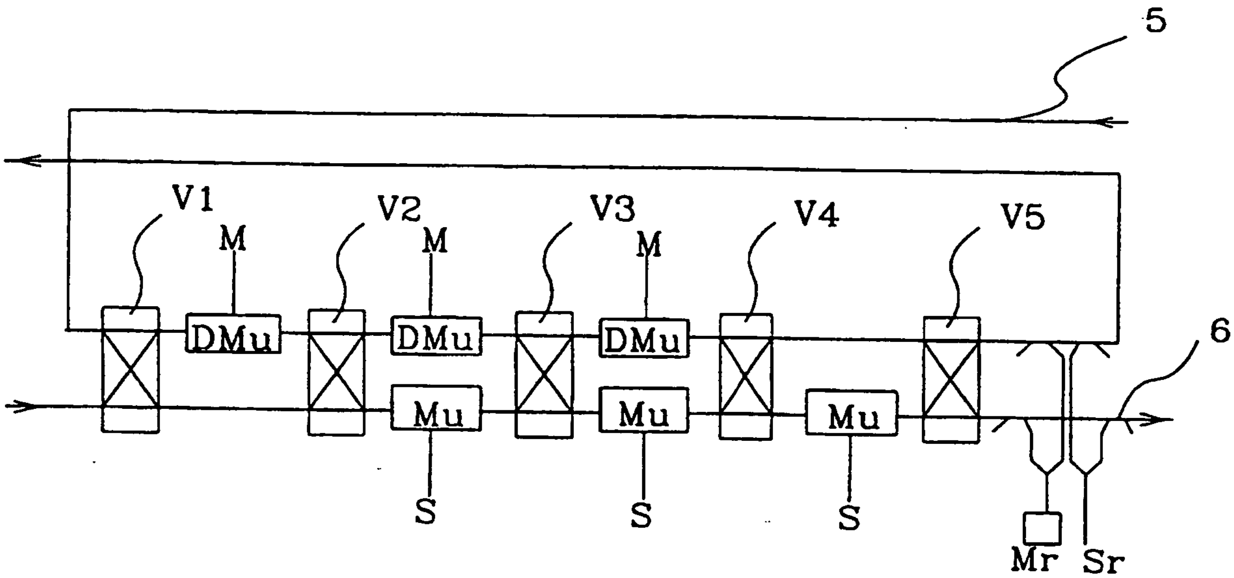

Fig.3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/00845

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04J 14/02, H04B 1/74, H04J 3/08
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04J, H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5457555 A (MORIYAMA), 10 October 1995 (10.10.95), column 7, line 45 - column 8, line 55 --	1-9
X	US 5506833 A (NEMOTO), 9 April 1996 (09.04.96), column 6, line 52 - column 7, line 20; column 8, line 10 - line 16, figure 7 --	1-9
A	EP 0570882 A2 (ALCATEL N.V.), 24 November 1993 (24.11.93), page 6, line 18 - line 38; page 19, line 27 - line 53, abstract -- --------	1-9

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT
Information on patent family members

06/08/97

International application No.
PCT/SE 97/00845

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